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THE RELATION OF PRACTICE TO INDIVIDUAL DIFFERENCES

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A fundamental problem of experimental psychology has to do with the way in which individual differences are produced. In general, it is apparent that such differences are manifestations, on the one hand, of differences in original nature, where heredity plays perhaps the predominant part; and on the other hand, the product of special education and experience.

On the mental side, the various psychological experiments afford us measures of individual difference in the particular functions with which they may be concerned. The question at issue concerns the extent to which these differences, as we meet them in every day laboratory experience, may be fundamental, inherent in the original nature of the individual, or may have been produced by special environment and training.

Some light on this question is here sought through the medium of the practice curve. Given functions in which the individual differences are sufficiently distinct, and in which the normal performance lies sufficiently far from the physiological limit, the following postulates may be formulated:

(1) The nearer the subject is to the end of his practice curve, the less prospect of improvement he has before him; and the further he is from the end of his curve, the greater his prospect of such improvement.

(2) If a high initial efficiency is the product of greater practice, then the expectation of further practice improvement is small; conversely, if a low initial efficiency is the product of lack of practice, then the expectation of improvement under special practice is great.

(3) If, on the other hand, a high initial efficiency be the product, not of a greater amount of practice, *but of greater ability to profit by a given amount of practice*, then the expectation of improvement under special practice is great; and conversely, if a low initial efficiency be the product of

little ability to profit by practice, then the expectation of improvement under special practice is correspondingly small.

The experimental problem is, then, to examine the relative frequency of application of the two latter propositions, not, of course, regarding them as mutually exclusive. This may be attempted in studying the practice curves of suitable tests in a number of subjects, observing the relation of initial efficiency to the amount of practice improvement.

The special precaution that must be taken in selecting such tests is to see that the most efficient performances in the normal distribution do not lie too close to the physiological limit of efficiency. If this be the case, as it is for example in the free association test, the poorer performances will simply catch up with those which are already near the limit; and while this has its specific effect upon the individual differences, it is not subject to interpretation by the above reasoning. As a criterion in this respect, the present experiments would suggest that the highest efficiency reached during practice by some subject should be at least twice as great as the highest efficiency of any subject at the beginning of special practice.

This condition is best met in the complicated arithmetical problems, where the physiological limit is indeed negligible when compared to the higher mental time; but in these tests are certain difficulties in scoring, as well as, perhaps, in the assurance of cooperativeness, that seemed to outweigh this advantage, and to favor the selection of a simpler form, as one of the addition tests. Here the necessity of a wide range of experimental material practically confined the choice to the Kraepelinian *Rechenhefte*. These contain vertical rows of the figures 1-9 in practically random order, 32 to a column, and 9 columns to a page, thus 18 to the two pages of the open *Heft*. The experimental task is to add each successive pair, i. e., the first and second digits, then the second and the third, etc. There are thus 31 additions to the column, 558 on the two pages of the open *Heft*. There are 24 pages, affording 11 double pages. There was scored the number of additions made each minute during five consecutive minutes, the total being taken to represent the efficiency of the performance. The additions were spoken aloud by the subject and followed upon a specially constructed key giving the correct answer in each case. False reactions can be noted in this way, but as they do not affect the results no account

is taken of them here; in general, the greater number of false reactions were made by the slower adders.

The other test was a modified *A*-test, consisting of 1000 of the figures 0-9, 100 of each, printed upon a space $5\frac{3}{4}$ " by $3\frac{3}{8}$ ", and so arranged that each figure occurred an equal number of times in any position. The subject is instructed to check as rapidly as possible the five zeros in each line, and the time required for this was taken to represent the efficiency of the performance. The two tests are hereinafter termed respectively the "addition test" and the "number-checking test."

A group of ten subjects underwent these tests daily, six days in the week, for a period of thirty experimental days. The subjects were nurses in McLean Hospital, five men and five women, of ages varying from 21 to 35 years. The work performed each day consisted of five minutes of addition, and on the first ten days one record of the number-checking test; while on the succeeding twenty days five records of the number-checking test were executed each day. The times of day were regularly the same for each subject. No noteworthy difference in cooperativeness was evident, but it did seem that, as indicated in a previous study, the monotony of the experiments affected the attitude of the women more than that of the men. On the other hand, it may well be that the factor of competition was stronger among the women, since, as is perhaps not unnatural, they appeared to exchange notes regarding their relative positions in the tests to a much greater extent than the men.

The results are, so far as possible, presented in the form of curves, showing the practice changes from day to day in each of the tests. Two sorts of curves are plotted for each test; those showing *absolute gains*, and those showing *relative gains*. In the case of the *absolute gains*, the standard of measurement is for the addition test, the number of additions spoken in five minutes; for the number-checking test, the standard of measurement is the number of zeros checked in one minute at the average rate maintained during the test. In the case of the *relative gains*, which are not reproduced here, the first day's performance in each test is taken to have the value of 100; and the curve is formed by the percentile values of this quantity attained in the succeeding day's practice. Here the curves are all reduced to a common denominator, and there is illustrated the proportionate amount of gain in each subject, independent of gross capacity.

The curves are presented and discussed in the following order:

Plate I, Absolute Gains in the Addition Test, Men.

II, Absolute Gains in the Addition Test, Women.

III, Absolute Gains in the Number-checking Test, Men.

IV, Absolute Gains in the Number-checking Test, Women.

The same color indicates the same subject, except as between the men and women; and the colors for the women subjects correspond to those already employed in a previous paper on practice effects in free association (this JOURNAL, vol. XXII, pp. 1-13).

Plate I, therefore, represents the absolute gains of the men in the addition test. Save in the case of ORANGE, the subjects here consistently maintained the same order of efficiency given in the initial performance. BLUE is not only the distinct leader throughout, but even draws slightly away from the nearest competitor; thus showing, in company with the greatest initial efficiency, the greatest absolute gain. While the record doubtless eliminated the initial spurt of practice, the performance of the last three days would certainly indicate that the limit of practice had not been reached. Substantially the same is to be said of the second subject, BROWN. Here the amount of absolute gain is during the earlier days of the practice, the greatest gain of all, and throughout closely approaches to that of BLUE. The limit of practice was evidently not reached. RED shows substantially the same absolute gain as BROWN, perhaps a little more, though it comes with greater slowness, and was, at the close of the experiments, apparently nearer its end. In the case of the subject with the lowest initial efficiency, GREEN, the absolute gain is least, and also slowest, saving the exceptional case of ORANGE. This subject, while commencing with an initial efficiency but slightly below that of BROWN, shows so little practice effect as to place his absolute gain quite in a class by itself for smallness, beside which those of the remaining subjects are relatively equal. The form of the curve would not indicate that the subject was near the limit of special practice, for it does not rise with exceptional slowness at the start, and, in fact, shows a relatively rapid rise at the close. In sum, it would then appear from these curves that the amount of absolute gain was for four of these subjects nearly equal, in spite of great differences in initial efficiency; the slight difference in absolute gain rather favoring those of greater initial efficiency.

The case of ORANGE apparently involves a fairly good inherent ability, with unusual insusceptibility to practice in this function.

The records also of the women as given in Plate II show some independence of initial performance and practice effect. Much the greatest absolute gain is shown by RED', who stands third in efficiency on the initial day. The speed ultimately reached by this subject is the greatest the writer has observed in the test, and was probably not far from physiological limits imposed by the speaking of the responses. The subject had reported that she could mentally add figures ahead of where she was speaking, though in a subsequent record, where the responses were not spoken, the performance was but little in excess of that with the spoken. The next greatest absolute gain, in a performance somewhat similar to that of the corresponding color with the men, is that of BLUE'. The initial performance is the best, and the absolute gain much the greatest of the four subjects besides RED'; nor was the end of practice in sight. The subject second in initial efficiency, GREEN', makes a very slow absolute gain, which, however, persists until it finally stands next to that of BLUE. It would evidently have progressed further. ORANGE', who occupies a distinctly lower place in initial performance, has an absolute gain more rapid at first, which soon ceases, apparently for good, at a level definitely below that of GREEN'. The smallest absolute gain is found in the subject with the lowest initial efficiency, BROWN'. In the amount of absolute gain there is much more difference among the women than among the men, and in sum they further illustrate the same thing as was indicated by the men. The greater absolute gain may well follow the greater efficiency of initial performance; this being now associated with the striking exception of RED', of the opposite character to that of ORANGE in the men.

Turning now to the records of the number-checking test (Plates III and IV), we find that in this function the curves of the different men subjects spread out like a fan, with the greatest absolute gain shown by the second subject, and the smallest by the subject of lowest initial efficiency. The record of BROWN dominates this plate as completely as those of BLUE and RED' the two preceding. BROWN nearly equals the best initial performance, and its ascent is the most rapid and the furthest. The best performance, some 38 seconds for the entire blank, must lie very near the physiological limit for the test. With an initial performance a little above, GREEN shows a much inferior practice effect, though pre-

serving a definite lead over the remainder. There is still some prospect for further gain, as also in the other subjects. Though RED is throughout distinctly slower than BLUE, their absolute gains are so commingled that superiority can scarcely be assigned to either. Both gain about equally at equal rates, though BLUE is more irregular near the beginning, RED near the end. As before in the addition test, the smallest absolute gain is shown by ORANGE, who has here also the lowest level of initial efficiency. Altogether, an association of superior initial performance with greater absolute practice improvement is seen to obtain also in these records.

Unfortunately the individual differences in this test among the women subjects turn out so small that not much light on the question at issue is to be derived from the records. So far as they go, however, they do not exhibit the parallel between absolute gain and initial efficiency of which the previous records have shown such marked instances. A strikingly anomalous record is given by RED', who, beginning at the highest initial efficiency, shows considerable drop in the practice curve, to fourth place; which is never improved upon. The absolute gain is, of course, much the smallest of any. This is the more noteworthy in connection with the very great practice effect of this subject in the addition test. The absolute gains of the other four subjects are much commingled, though BLUE' has rather the most; in point of initial efficiency this subject stands fourth. Next come ORANGE' and GREEN', whose gains are practically equal, as are also their initial positions, though ORANGE', with the slightly inferior initial position, seems to gain a little more. As in the addition test, BROWN' shows the lowest efficiency throughout, and the smallest absolute gain with the exception of RED'; but on the whole, the greater absolute gains have not here been associated with greater efficiency of initial performance.

Nor would the number of observations be sufficient to establish a universal principle, even were they in general accord. Definite things do, however, stand out in regard to certain individual records. It is patent from such cases as BLUE and BLUE' in the addition test and BROWN in the number-checking test, that high initial efficiency in no way precludes, but on the other hand, may frequently indicate, the expectation of considerable practice improvement. On the other hand, ORANGE and BROWN' are examples of slight susceptibility to absolute gain, apt to be associated with lower efficiency of performance. It is not apparent that such records



PLATE I. Absolute Gains in the Addition Test, Men.



PLATE II. Absolute Gains in the Addition Test, Women.



PLATE III. Absolute Gains in the Number-Checking Test, Men.

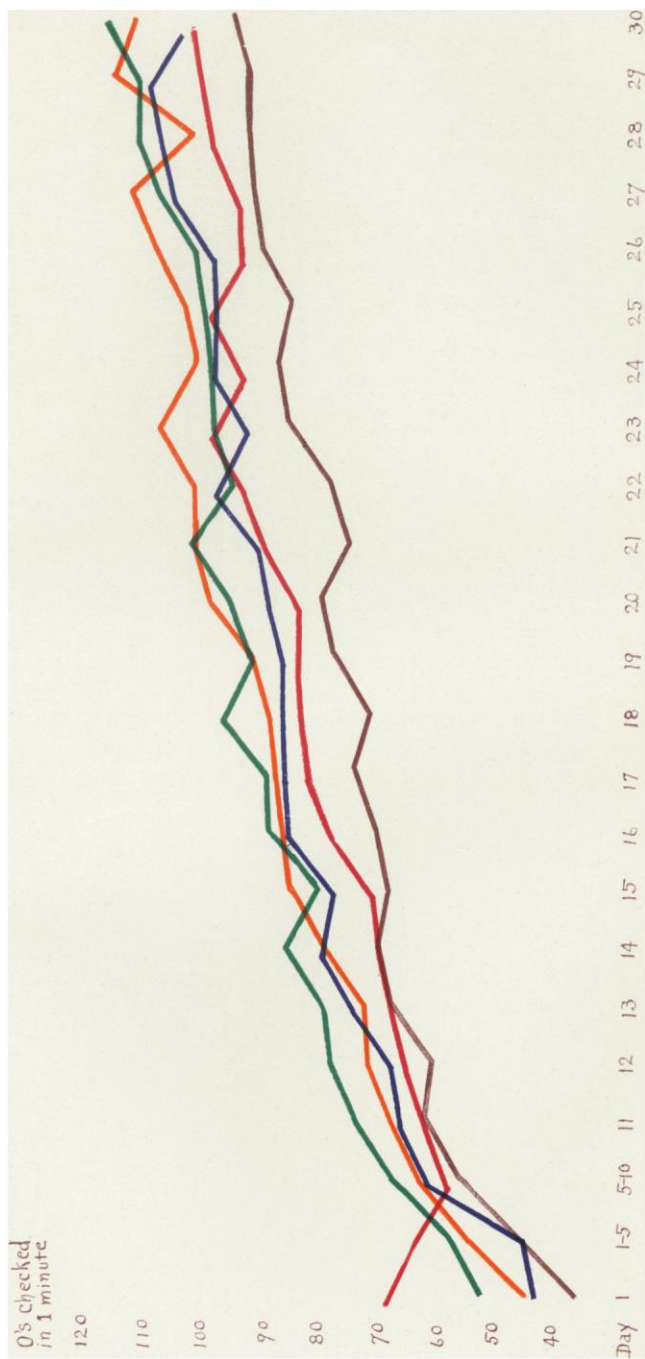


PLATE IV. Absolute Gains in the Number-Checking Test, Women.

represent the end of the practice curve for the subject concerned. We are evidently confronted, then, with cases indicating a high initial efficiency as a manifestation of superior ability to profit by practice, or plasticity; and on the other hand, with cases exhibiting a lower initial efficiency, with minor possibilities of practice improvement.

As has been explained, the curve for the relative gains reduces the results for the different subjects to a common denominator, taking the initial performance in each case as 100, and expressing the subsequent ones in their percentile relation to it. The curves in each case thus start at the same point. As would naturally be expected, the relative amounts of ascent differ largely from those in the curves for the absolute gains. Thus in the curves showing the relative gains in the addition test for men, it is seen that the greatest relative gain has been made by RED, whose regular position was third in the curves for absolute performance. This subject has reached an efficiency of some 210% of initial capacity. GREEN, somewhat slower absolutely, also does not gain so much relatively; his curve being pretty consistently below that of RED. With their high initial performances, the relative gains of BROWN and BLUE drop still further below; for they require a much greater absolute gain than the others to reach their percentile level. The relative gain of ORANGE is the smallest of all, the inferiority being more marked here than in Plate I, owing to the relatively high initial performance.

The curves showing the relative gains in the addition test for the women are dominated by the striking practice improvement of RED'. But it is noteworthy that BLUE', who had the greatest initial efficiency, is second in point of relative, as well as in absolute gain. BROWN', whose absolute efficiency was lowest, is next, while ORANGE' shows a relative gain distinctly above that of GREEN', though in absolute performance distinctly below it. GREEN', showing the least relative gain, is third in absolute gain, second in initial performance. Here also it is seen that the relative gains tend rather to follow the reverse order of the absolute performance.

But in the case of the men in the number-checking test, it is again noticeable that BROWN, who not only had the quickest record in the number-checking test and made the greatest absolute gain in it, has with equal definiteness accomplished the greatest relative gain. The relative gains in the other records are nearly equal, which should be taken in connection with the fact that the range of these records in gross efficiency of performance is nearly 2:1. Here, then,

there is certainly no negative relation between gross performance and relative gain.

The curves are further apart in the case of the women, and show a reversed relationship to the absolute performances. They are greatest in BROWN', whose absolute efficiency is lowest, and next in ORANGE', BLUE' and GREEN', respectively. But neither in absolute nor relative gains are the individual differences especially clear-cut.

To sum up, the orders of precedence in the different functions of the two tests may be given as follows:

ADDITION TEST (MEN)

Initial Performance	Absolute Gain	Relative Gain
Blue	Blue	Red
Brown	{Brown}	Green
Orange	{Red }	Brown
Red	Green	Blue
Green	Orange	Orange

ADDITION TEST (WOMEN)

Initial Performance	Absolute Gain	Relative Gain
Blue'	Red'	Red'
Green'	Blue'	Blue'
Red'	Green'	Brown'
Orange'	Orange'	Orange'
Brown'	Brown'	Green'

NUMBER-CHECKING TEST (MEN)

Initial Performance	Absolute Gain	Relative Gain
Green	Brown	Brown
Brown	Green	Red
Blue	{Red }	{Green }
Red	{Blue}	{Orange}
Orange	Orange	Blue

NUMBER-CHECKING TEST (WOMEN)

Initial Performance	Absolute Gain	Relative Gain
Red'	Blue'	Brown'
Green'	Orange'	Orange'
Orange'	Green'	Blue'
Blue'	Brown'	Green'
Brown'	Red'	Red'

Certain limitations in the use of either absolute or relative gain as a criterion of practice effect will doubtless have

suggested themselves to the reader familiar with the properties of the practice curve. It is scarcely to be supposed that a practice improvement of n units means the same thing when added to an initial efficiency of a units as when added to an efficiency of $2a$ units. *Ohne weiteres*, however, it should scarcely be said that one is more or less than the other. If, as has been sometimes done, we simply suppose higher initial efficiency to mean that the function is nearer the end of the practice curve, then obviously the gain of n units is more difficult for the individual who has a higher initial efficiency. The present results indicate that this reasoning rests upon a very insecure foundation, for it here repeatedly appears that the gain of n units is quite as likely if not more likely to take place upon an efficiency of $2a$ than of a . Another point must be mentioned in this connection, namely, that when the function is originally measured in terms of amount performed in a given time, as it is in the addition test, the amount of work performed in practice is much greater in the case of the more efficient individuals. Thus when the less efficient A has made as many additions as the more efficient B , he may have improved as much, though taking over twice the time to do it. If this factor were of essential importance, then the low initial efficiencies should, in comparison with the other subjects, show a much greater absolute gain in the number-checking test, where they do equal work, than in the addition test, where they do less work. With the men, this is not at all the case. With the women there is perhaps a little more semblance of it, but on the whole, the number-checking test scarcely seems to have favored the practice of the poorer individuals any more than the addition test. This, with its implication of a law of diminishing returns from individual practice series, leads into the great series of problems regarding the most efficient way to practise. A definite amount of work doubtless produces different practice effects according to different apportionments to the same individual, just as it illustrates different practice effects when, as here, it is similarly apportioned to different individuals.

According to presentation in terms of time or amount, the phenomena of the absolute gain present a curious dilemma. The curves have been plotted in terms of amount performed in a given time, and if the absolute gains of the more efficient individuals are greater than those of the less, the records assume the fan-shape recorded most perfectly in Plate II, the distances between the subjects becoming greater. Now if, instead, the curves were plotted in terms of time, they would

approach each other as they neared the lower limit of quickness, and the distances between the subjects would become less. Compare the cases of a worker, C, making 100 artificial flowers per hour, and one, D, who makes 50 in the same period. With given practice, C becomes able to make 175 per hour, and D able to make 100. The gains compare as follows according to the way they are considered:

C has made an absolute gain of 75 pieces.

D has made an absolute gain of 50 pieces.

C has made a relative gain of 75 per cent.

D has made a relative gain of 100 per cent.

C has decreased the time required for 100 pieces by 26 minutes.

D has decreased the time required for 100 pieces by 60 minutes.

Nevertheless, there can be but little doubt that any manufacturer would consider C as having improved the original lead over D. If for artificial flowers we substitute distance covered in yards, C would certainly be a further distance ahead of D at the second timing than at the first; nor according to the observed properties of the practice curve, would C's lead be likely ever to become less.

And further, since the ratio of gain is not constant in the practice curve, but tends to decrease, the relative gain cannot itself be employed as a criterion of practice effect, though it is similar, whether time or amount is taken as the unit of measurement. If one considers equal percentile changes, no matter what their bases, to represent equal practice effects, one runs counter to our most fundamental conceptions of the nature of the practice curve. One can scarcely require that a function of 600 units shall show 300 units of improvement before it shall be judged to have improved equally to an increase of 50 units from a basis in another individual of 100 units. If a function, x , begins at 600 units and increases to 900, it should certainly be accounted more plastic than an identical function, y , which begins at 100 and in the same time increases to but 150. It is another question whether y should be accounted more plastic than z , which begins at 500 units and rises under the given conditions to 550. If y reaches the 500 mark it will not, presumably, be able to reach 550 as quickly as it did 150 from the 100 mark, therefore, not so quickly as z increased from 500 to 550. On the other hand, y has already increased in capacity by 50%, which z is not likely ever to do now. It would depend upon whether z 's advanced position were

to be regarded as constitutional, or due to an advanced position in the practice curve. If the constitutional ability of *z* began at or near that of *y*, it must be reckoned as more plastic; if it is fairly represented by the 500 unit mark, it is obviously less so.

But of course we cannot know objectively, from any isolated or initial performance, what part of the function's practice curve it represents. This we must know, to judge of the amount of plasticity represented by a given practice gain. From the form of the actual practice curves we must judge whether there are sufficient differences in the stages of practice to modify the interpretations of the gains accordingly. Except where such differences are indicated, and they scarcely seem to be in the present results, there would seem to be two criteria of greater plasticity. First, a greater absolute gain, in terms of amount, upon a basis of greater initial performance. Secondly, a greater relative gain leading to a greater efficiency of terminal performance.

According to these criteria, the records show various instances of individual differences in capacity apparently the result of differences in the fundamental plasticity of the function. The inferior showing of *ORANGE* in the number-checking test, for example, is essentially due to something other than mere lack of practice, for in such a case the relative gains would but have been so much the greater, as they were in *RED'* for the addition test. On the other hand, the performance of *BLUE'* in the addition test is not a matter of starting nearer the end of the practice curve, for not only has she a better initial performance, but gains more, both absolutely and relatively, than *BROWN'*, *ORANGE'* or *GREEN'*. Her superior initial performance is to be looked upon rather as a matter of fundamentally superior aptitude in the function,¹ which continues to manifest itself in greater practice improvement. The same is to be said of the record of *BROWN* in the number-checking test. The superior aptitude expresses itself in both superior actual performance and superior ability to profit by practice. Or when the record of *ORANGE* in the addition test is compared with that of *BLUE*, it is seen that *ORANGE* starts not only distinctly below the absolute level of *BLUE*, but fails to gain absolutely or even relatively as much. Here the function in *ORANGE* is certainly less plastic.

Ultimately that individual is the most plastic who is able

¹In this connection, the reader may be reminded of the especially good adaptation of this subject in the free association test. *Am. J. of Psych.* XXII, Plate facing p. 2.

to improve the most. If we may reckon the original ability in the function as approximating zero, as it may be considered to do at birth, then the individual who stood higher at the beginning of special practice would be the individual who had, up to that time, improved more. This previous improvement might carry with it less, might carry with it greater prospect of future improvement; the present experiments seem to indicate that it carries with it the prospect of greater future improvement more frequently than less. But the different exceptions show that we ought in no wise to consider the plasticity of a function as always the determining factor in its efficiency at the beginning of special practice; the case of ORANGE in the addition test may be quoted in illustration. It thus seems likely that certain factors of neural constitution, independent of plasticity, may determine high or low efficiency at the beginning of special practice. This is what is meant by the "constitutional" factors in ability as cited above; and though undeniably complicating the situation, they seem a necessary postulate to its proper formulation.

We have then, finally, (1) a difference in the individual's (*resp.* function's) fundamental plasticity, i. e., ability to profit by practice, (2) a difference in the actual amount of practice experienced, and (3) constitutional factors, independent of plasticity, in the nervous system. The inquiry has been concerned with the relative importance of these factors in producing the individual differences seen at the beginning of special practice. In the present instances, their influences would seem to operate in about the order named.

Further points of inquiry concern the results as they illustrate other important properties of the ability to improve by practice. To what extent does it seem to be a fundamental attribute of the individual, or distributed independently among various special functions? The performance of RED' is an illustration of extreme plasticity in one test combined with an equally striking lack of it in the other. The gain of BROWN in the number-checking test is quite out of proportion to that in the addition test. On the other hand, ORANGE and BROWN' seem to furnish instances of a lack of plasticity in both tests; for BROWN', though making the greatest relative gain in the number-checking test, in neither case gains sufficiently to leave a fairly definite lowest place. How far such a presence or lack of plasticity might be general, the experiments, of course, do not indicate; but it seems quite certain that the degree of plasticity is sometimes determined with regard to the special function.

An additional point concerns the daily fluctuations in the practice curves after they have ceased their uniform rise. Like other practice curves, the daily records in both tests are serrated; going now up, now down. The causes of such episodes in the curve might be general, affecting the whole organism, or confined to the particular functions involved. Some estimate of the extent to which general or special causes are involved might be derived through comparing the curves of the two tests, noting whether there tended to be a coincidence of marked cusps in the curves.

The testimony of the curves in this regard is quite unequivocal. If one superposes the two curves of each subject for the last twenty days of performance, it is evident that the curves rise and fall with practical independence of each other. Extreme rises or falls in one may be accompanied by rises, falls or no change in the other function. This is interesting in connection with the fact that such introspective data as were given seemed to be equally independent of the performance in either test; nor did the subjective estimate of efficiency always accord with that actually attained. The performance in the two tests would seem to be determined by factors largely outside the scope of introspection; and the organic processes giving rise to a feeling of unfitness for the task must be of considerable intensity to show an actually unfavorable effect upon its performance. While it is not necessarily true that a general change in bodily condition would affect both tests in the same direction, yet the comparative independence of their fluctuations makes it extremely probable that different factors of bodily condition are operative upon them, and throws an interesting side-light upon the complexity of the factors affecting the performance in two by no means unrelated experiments.

The groups of subjects are perhaps too small to expect any special sex differences to be illustrated. Even though consistent differences between such groups appear, they may often be the result of chance. In the addition test the performance of the women is much more variable than that of the men, in the number-checking test it is much less so. In neither case is there much difference in the average performance. More significant perhaps is the question of a sex difference in susceptibility to practice. In the addition test the balance is about equal; and in the number-checking test, the variability of the records makes any generalization hazardous. A far-reaching sex-difference in susceptibility to practice seems, so far as concerns the functions covered by these experiments, quite improbable.

The secondary findings in these experiments may then be enumerated as (1) the specific character of efficiency in the tests themselves, (2) the specific character of plasticity in them, (3) the specific character of such episodic changes in the organism as influence their efficiency, and (4) the absence of any notable sex-difference throughout.

The more significant result would seem to be the indication that a superior performance at the beginning of special practice is not necessarily, nor even probably, attained at the sacrifice of prospects for future improvement. A high initial efficiency may carry with it as much or more prospect of improvement under special practice than a low one. It was not because the favored individual had had more of the general experience enabling him to meet the experimental situation better, but because he possessed the native ability to profit more by such experience, general and special, past and future. Not practice, but *practiceability*, is responsible for the superior position of such an individual; and, in broader aspect, not education, but educability.

The present results seem then to be another drop in the current that sets towards the interpretation of vital reactions as primarily limited and determined by factors of original nature, upon which a more incidental coloring is imposed by those of experience and environment.